

# Incorporating a Robot into an Autism Therapy Team

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*User interface technology and a therapy model create a limited, “low-dose” role for a robot on a therapy team for children with autism spectrum disorder.*

**A**utism spectrum disorder (ASD) refers to a group of pervasive developmental disorders that share common deficits in social interaction and communication.<sup>1</sup> Such deficits may be manifested as the inability to use non-verbal behaviors (such as eye contact and facial expressions) and to regulate

social interactions. Furthermore, about 50 percent of children identified with ASD present with insufficient language for effective communication.<sup>2</sup> Their spoken language might be characterized by repetitive or idiosyncratic speech, and the affective component may be limited.<sup>3</sup>

Social interaction doesn't motivate or engage children with ASD the same way it does their typical peers; in fact, they might show more preference for objects over people than do their peers with other developmental disabilities.<sup>4</sup> For this reason, speech and language intervention designed for children with other developmental delays might not suit the needs of this population. Children with ASD might require more extraordinary effort to elicit social interaction.

Consequently, therapies designed to assist children with ASD necessarily involve a team of people. At the Brigham Young University (BYU) Comprehensive Clinic, this team includes a primary therapist, a secondary therapist, a therapy supervisor, and the child's caregivers. Even with this extraordinary effort, interventions that reliably yield improvements in social interaction and communication are still needed, especially for very low-functioning children.

Evidence is growing that robots are engaging to many children across the autism spectrum.<sup>5-7</sup> Generalizable child-human interactions are the sine qua non of assistive robotics for ASD therapy, however, and social engagement with a robot is not a goal but rather a means for helping such children

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interact socially with other humans. Indeed, a single-minded focus on child-robot interactions could potentially exacerbate problems associated with ASD, such as echolalia or perseveration on robotic movements or sounds.

Fortunately, there is mounting evidence that robots can help trigger social interactions between a child and another person.<sup>5</sup> Such evidence has yet to suggest improved interactions that endure or that generalize outside of a lab or clinic, however.

In this article, we present a description of the teaming environment used to provide therapies to children with ASD, identify the role a robot can perform on this team, and describe robot design and user interface technologies that let the robot perform this role within a broader context of the team's shared intentions. A case study provides compelling preliminary evidence that this team-based robot-assisted approach merits careful, ongoing study.

### Embedding Low-Dose Robotics in a Team

The team-based approach to ASD therapy is based on practices in the BYU Comprehensive Clinic, which serves children and adults with a wide range of speech and social deficits. The clinic uses professionally supervised graduate student therapists as part of their preparation to become practicing clinicians.

For children with ASD, the therapy team consists of the following roles:

- the primary clinician, who is responsible for the execution of a therapy plan;
- a secondary clinician, who may provide hand-over-hand support for a child with ASD during the therapy session;
- the therapy supervisor, who works with the primary and secondary

clinicians to assess the child, develop a therapy plan, and evaluate therapy sessions; and

- caregivers, who work with the therapy supervisory and clinicians to assess, set goals for, and evaluate progress of the child.

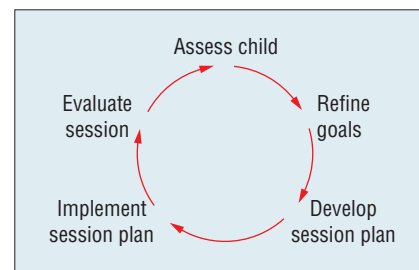
These team members follow a roughly sequential process (see Figure 1) that begins with an initial assessment and a careful evaluation of the child, and then iterates through the cycle while the child participates in therapy.

Children with ASD come to the clinic once or twice each week for 50-minute sessions tailored to help them in a set of specific areas. Before each session, clinicians develop several activities designed to provide structured interaction for targeted social or developmental skills. During therapy, the children interact with the clinicians and often a parent, with five to 10 potential activities per session.

Here we focus on those activities related to the development of social communication. Two key social behaviors targeted in the therapies are

- responding to joint attention by, for example, following an eye gaze, head turn, or pointing gesture; and
- initiating joint attention by, for example, using eye gaze, pointing, and gestures to direct the attention of a social partner to a referent of interest.<sup>8</sup>

For ethical reasons, we decided before beginning the work that we would use robot-based activities for no more than 20 percent of the available therapy time, or for approximately 10 minutes of a 50-minute session. Although ethics motivated the limit initially, it is consistent with the therapeutic goal of producing



**Figure 1. Stages of the therapy team process. The team works through an iterative process of assessment, goal-setting, planning interventions, and implementing interventions.**

generalizable social skills in the child. Training a child to interact with a robot is less likely to produce child-human social skills than training a child to interact with a clinician or caregiver.

We refer to this limit as a “low-dose” role, targeting two specific functions: engaging the child and catalyzing social interactions. Our results suggest that such a low-dose robotics approach can not only simplify a robot's design and behaviors but also produce generalizable child behaviors. Simply put, by designing the robot to be part of the therapy team, we can simplify the robot design problem and make the therapies more effective.

The robot's role in therapy can be summarized in the following steps:

1. Engage the child's attention.
2. Trigger dyadic social exchanges between the child and the robot.
3. Support triadic social exchanges between the child, the clinician or caregiver, and the robot.
4. Phase out in favor of dyadic social exchanges between the child and the clinician or caregiver.

Other research has supported the plausibility of fulfilling these steps (see the sidebar, “Related Work on Robots and Autism Therapy”). For example, Kerstin Dautenhahn has described observations from the Autonomous Mobile Robot as a Remedial tool for Autistic Children (AuRoRA) project, which studies

## Related Work on Robots and Autism Therapy

Several researchers have demonstrated the potential for engagement between a child with autism spectrum disorder (ASD) and a robot. Hideki Kozima and his colleagues reported that children who interacted with the Infanoid robot became engaged enough with it to move through phases of neophobia, exploration, and interaction.<sup>1</sup> Others have offered evidence that children with ASD tend to engage with robots differently than their typically developing peers do.<sup>2,3</sup>

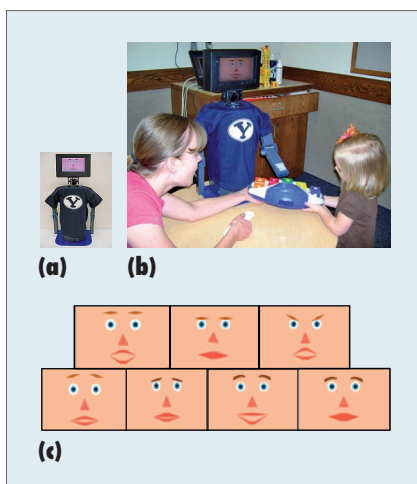
Beyond simple engagement, researchers have explored using robots to improve social responsiveness in children with ASD and to help create relationships with humans.<sup>4–6</sup> Children who participated in a study using Robota, a doll equipped with motors and imitative capabilities, exhibited signs of engagement and imitative behavior toward the robot.<sup>7</sup> Similarly, studies with Kaspar indicated that children displayed social interactions with the robot.<sup>8</sup>

Kozima and his colleagues also conducted a longitudinal study lasting three years in which children with ASD interacted with the Keepon robot during their time at a daycare center.<sup>1</sup> These children were reported to engage spontaneously in dyadic interactions with the robot.

Several studies report both dyadic child-robot interactions and triadic interactions between the child, the robot, and an adult.<sup>9</sup> Ben Robins and his colleagues observed children with ASD communicating with an accompanying adult about Robota, and children with ASD were interested in sharing the experience of Kaspar with the researcher in the room.<sup>7</sup> Kozima and his colleagues also reported instances involving Keepon in which a child engaged in triadic interactions with the robot and the caregiver.<sup>1</sup>

## References

1. H. Kozima, C. Nakagawa, and Y. Yasuda, "Designing and Observing Human-Robot Interactions for the Study of Social Development and its Disorders," *Proc. IEEE Int'l. Symp. Computational Intelligence in Robotics and Automation*, IEEE, 2005, pp. 41–46.
2. L. Gomes, "Smart, Robotic Toys May One Day Diagnose Autism at Early Age," *Wall Street J.*, 26 Oct. 2005, p. B1.
3. B. Robins, K. Dautenhahn, and J. Dubowsky, "Does Appearance Matter in the Interaction of Children with Autism with a Humanoid Robot?" *Interaction Studies*, vol. 7, no. 3, 2006, pp. 479–512.
4. K. Dautenhahn, "Roles and Functions of Robots in Human Society: Implications from Research in Autism Therapy," *Robotica*, vol. 21, no. 4, 2003, pp. 443–452.
5. D. Feil-Safer and M. Matarić, "Robot-Assisted Therapy for Children with Autism Spectrum Disorders," *Proc. Conf. Interaction Design for Children (IDC 08)*, ACM, 2008, pp. 49–52.
6. G. Pioggia et al., "An Android for Enhancing Social Skills and Emotion Recognition in People with Autism," *IEEE Trans. Neural Systems and Rehabilitation Eng.*, vol. 13, no. 4, 2005, pp. 507–515.
7. B. Robins et al., "Effects of Repeated Exposure to a Humanoid Robot on Children with Autism," *Designing a More Inclusive World*, S. Keates et al., eds., Springer, 2004, pp. 225–236.
8. J. Wainer et al., "Collaborating with Kaspar: Using an Autonomous Humanoid Robot to Foster Cooperative Dyadic Play among Children with Autism," *Proc. 10th IEEE-RAS Int'l Conf. Humanoid Robots (Humanoids 10)*, IEEE, pp. 631–638.
9. D. Francois, S. Powell, and K. Dautenhahn, "A Long-Term Study of Children with Autism Playing with a Robotic Pet: Taking Inspirations from Non-directive Play Therapy to Encourage Children's Proactivity and Initiative-Taking," *Interaction Studies*, vol. 10, no. 3, 2009, pp. 324–373.



**Figure 2.** The robot Troy. (a) The robot had a seven-inch computer screen for a face and movable arms; (b) a clinician used a Wii controller to direct Troy to move, change its display, and speak or sing; and (c) Troy's face could express a range of basic emotions.

if and how robots can serve an educational or therapeutic role as toys for children with autism.<sup>9</sup> She observed that

- children wanted to interact with the robot for 10 minutes or more,
- children were more interested in the robot when its behaviors were interactive, and
- most children showed more interest in the robot than in a similar-looking but nonrobotic toy.

We know of no literature where the robot was used in a low-dose role as part of a larger therapy team, however.

### The Robot's Physical Form

Researchers and clinicians at the BYU Comprehensive Clinic identified two clear criteria that the robot must

satisfy to fulfill a role in the ASD therapy team.<sup>10</sup> First, it must have a form factor, appearance, and mobility that is likely both to engage a child with ASD and to trigger dyadic and triadic social interactions. Second, it must be capable of performing several pro-social clinical activities such as taking turns, imitating movement, and performing songs with actions.

With respect to the first criterion, the robot (called Troy) was designed to be the same size as an average 4-year-old child. Troy is 25 inches tall with two arms 12 inches in length (see Figure 2a). Each of Troy's arms has 4 degrees of freedom: raising and lowering, adduction and abduction, medial rotation of the forearm, and extension and flexion of the elbows. The robot uses its arms for simple interaction activities, such as pushing

a toy car, pushing buttons, pointing, waving hello, and recreating the hand actions associated with children's songs<sup>11</sup> (see Figure 2b). The robot doesn't need to move around a room, so Troy is a stationary upper-body robot that can sit on the ground or a table while therapists control its interactions. We mounted Troy on a base to provide stability, and connected it to a laptop computer via cords extending from the posterior torso. The laptop computer sat on a countertop out of the children's immediate reach.

The activities in a typical therapy session include affect expressed through sound and facial expressions. Consequently, we equipped Troy with a seven-inch computer screen encased in plastic to serve as its head. The screen presented a simple face that could display happy, sad, or neutral emotions. (See Figure 2c.) Two remote-control servo motors between the screen and the body allowed head movement along horizontal and vertical planes. A speaker inside the torso gave Troy speaking and singing capability. A student from BYU's Music-Dance-Theater program recorded customized greetings for each participant, along with positive-affect sounds (such as "Woo hoo!") and negative-affect sounds (such as "Whoops!"). We added simple songs to the robot's repertoire during the case study described later.

We designed the robot behaviors to promote turn-taking and imitation behaviors. The primary clinician would talk with the child, trigger autonomous robot behaviors via a Wiimote (the remote control for a Nintendo Wii gaming system), and lead the interactions. The secondary clinician would provide hand-over-hand support to gently guide the child in turn-taking. A typical turn-taking activity would start with the robot pushing a truck to the child, followed

by a request from the primary clinician that the child push the truck back to the robot. The secondary clinician would help the child as needed. The primary clinician would then "ask" the robot to push the truck to the clinician, who would push the truck back to the robot. The child-robot turn-taking would repeat, and then the child would be asked to push the truck to the therapist, followed by the therapist pushing the truck back to the child.

This turn-taking example is consistent with the goal of producing generalizable child-human social interactions. The therapy begins with therapist-supported dyadic interactions between the child and the robot; proceeds to robot-mediated triadic interactions between the child, robot, and therapist; and then engages the child in child-therapist interactions. Perhaps most importantly, the robot is only fulfilling its role in 20 percent of the interaction time. The remaining 80 percent of therapy time is dedicated to other social and developmental needs of the child.

### User Interface

We designed the user interface on the basis of the theory of shared intentions, which is a defining characteristic of effective teaming.<sup>12</sup> The team-based therapy process illustrated in Figure 1 produces several explicit representations of shared intention. These include written plans for each session, documentation of assessment and diagnostic activities, explicit therapy goals, and summaries of the sessions. This body of documentation serves the human members of the team well, but not the robot. Instead, we programmed shared intention into the robot between therapy sessions and developed technology to let the therapist tell the robot what to do at various times in the therapy session.

We contend that for robot-assisted therapy to flourish, therapists must program robots.<sup>13,14</sup> Programmer expense is one reason for this, but more importantly, programmers aren't part of the therapy team and don't help construct and refine shared intent; they probably won't completely understand what robot behaviors the therapist really needs. Since programming is generally outside the purview of therapists, we developed technology that lets them program robot behavior according to the principle of encoding shared intent.

Figure 1 illustrates that most of the work on constructing and refining shared intention actually takes place outside the therapy sessions. Between therapy sessions, the therapy team evaluates progress and decides what the child needs to progress. Thus, we target "between session" programming, wherein the therapist programs the robot to perform specific behaviors targeted to specific therapeutic objectives. The portion of the shared intent represented to the robot is a choreographed sequence of behaviors that describe a contingency plan for what the robot should do given certain inputs from the therapist.<sup>15</sup>

We have developed a prototype drag-and-drop visual programming user interface that lets a therapist arrange existing robot behaviors in sequences and map those sequences to an input device.<sup>16</sup> Figure 3 shows the user interface as it appeared during use in the clinic.<sup>17</sup> The user places blocks that represent robot actions or user input, then connects the blocks with arrows to indicate program flow. In this way, the user chooses a few robot actions and then assigns buttons on a remote control to initiate those actions. Importantly, the user interface explicitly represents the state machine that encodes the contingency plan for



switching between robot behaviors.

Two therapists successfully used a prototype version of this interface to create choreographies for the robot, and then they used these choreographies in therapy with children with ASD. Three other therapists who hadn't used the robot or user interface were also able to create choreographies after 10 minutes of training. These results aren't statistically significant, but they do demonstrate that it is possible for a therapist to encode the robot's role explicitly in a program that the robot can execute.

During a therapy session, the clinician must be capable of following a series of paths through the state machine depending on how the child is acting or reacting. We required the clinician to trigger the robot's behavior, because understanding the state and intent of the child within the scope of the therapy is currently beyond the capabilities of the robot. Indeed, understanding the state and intent of a low-functioning child with ASD is often beyond the capabilities of a single human, which is why we employ a therapy team.

Therapy is a high-workload environment for the therapist, who needs to interpret the child's behaviors in some social or regulatory context, facilitate child-directed activities, mitigate negative child behaviors, and select and engage in activities that can promote both the planned and unanticipated therapeutic objectives. Because of this, the therapist doesn't have much time to interact with the robot. Moreover, as a practical constraint, children with ASD might find electronic devices engaging, so any

sort of overt remote control for the robot could distract them from the therapy (although in at least one case, a remote control facilitated child-adult interaction<sup>18</sup>).

For within-session control during the case study, we used a Nintendo Wii remote for our input device. This remote is small, wireless, easy to use without looking, and readily available. We currently use only the buttons on the remote, and not the other sensors such as the accelerometer or infrared camera.

### Intervention Case Study

Unlike much other previous work regarding using a robot to help children with ASD, our study focuses less on the child and more on the team of child, clinicians, caregivers, and robot. Simply put, our goal is to help clinicians by developing robot and user interface technologies that let the robot fulfill a low-dose but critical role in team-directed therapy. We undertook a trial to evaluate this team-centered approach.

### Participants

Two children, three-year-old Alex and eight-year-old Chris, participated in the intervention. (The boys'

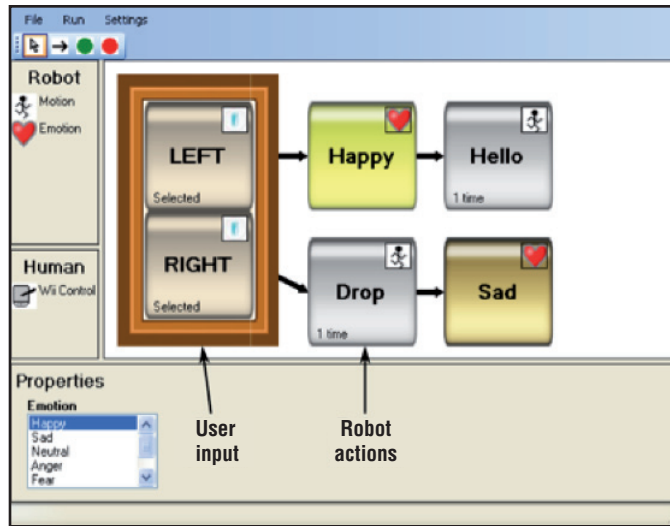
names have been changed for the sake of privacy.) Both boys were identified with ASD, and both were enrolled in special services through their school districts. Alex and Chris had been followed in the BYU Speech-Language Pathology Clinic for intervention targeting joint attention and social-engagement behaviors. Although Chris was older and higher functioning than Alex, both boys demonstrated mod-

erate to severe levels of impairment in social communication, as well as restricted interests and repetitive behaviors (such as spinning a puzzle piece or fixating on the same toy). Neither boy had made marked progress on intervention goals in the previous six months. We obtained approval from the Institutional Review Board and informed consent from the parents before beginning the study.

### Procedures

Each participant came for 16 treatment sessions over a three-month period. Each session consisted of 40 minutes of treatment (without the robot) as part of an ongoing intervention program, followed by about 10 additional minutes devoted to interaction with the robot. This organization of each treatment is consistent with the team-based approach to the therapy, dedicating the bulk of the resources to human-child interactions but using the robot to engage the child and promote dyadic and triadic interactions.

The therapeutic interactions involved the child, a primary clinician (who was a graduate student), a secondary clinician (also a graduate student) to provide hand-over-hand



**Figure 3. The prototype programming interface. The therapist could arrange robot behaviors in sequences and map those sequences to an input device.**

prompts, and the child's parent (when available). Using the programmed robot contingency plan, the primary clinician instigated a series of interactions in which that clinician, the child, and the robot participated in reciprocal activities (such as waving, pushing toys to each other, and singing songs with actions). The expression of positive or negative affect was intrinsic to each interaction.

### Assessments

We conducted pre- and post-treatment assessments of social engagement (not involving the robot) in four contexts: child-parent interaction, clinician-child interaction, triadic interaction (with both clinicians), and child interaction with an unfamiliar adult.

For the child-parent interaction, we provided the parent with several toys, including trucks, a bus, helicopters, dolls and doll accessories, and blocks. We asked the parent to interact with the child as he or she normally would for 20 minutes. For the clinician-child assessment, the clinician introduced various toys, including dolls, doll accessories, a toy truck, blocks, and a toy garage. The clinician handed the child each toy. If the child played with the toy appropriately, the clinician commented on the child's play and attempted to elicit joint attention with the child. If the child did not play with the toy appropriately, the clinician modeled appropriate play, gave the toy to the child, and attempted to establish joint attention.

For the triadic interaction, the child's primary and secondary clinicians interacted with the child. The clinicians initiated 20-minute play sequences in which they encouraged the child to take a turn pushing a toy car, hitting a tambourine, operating mechanical toys, or pushing a ball. For the unfamiliar adult interaction, a

clinician not familiar to the child introduced several toys, including wind-up toys, a ball, a hat, a comb, and a book, and attempted to elicit joint attention similar to the clinician-child interaction. The unfamiliar adult also sang two songs with actions. This assessment lasted approximately 10 minutes.

We also conducted pre- and post-treatment assessments using the same materials, individuals, and methods, with the exception of the interaction with an unfamiliar adult. In this case, a different adult elicited the post-treatment assessment to maintain the unfamiliar status. We filmed all interactions with both a stationary and a handheld video camera. Altogether, the assessments, designed to evaluate whether the robot promoted child-human interactions, used various members of the therapy team plus two unfamiliar adults.

### Analysis

We analyzed the pre- and post-treatment assessments using a coding system based on the work of Connie Kasari and her colleagues.<sup>19</sup> Behaviors analyzed included initiating social engagement and responding to joint social engagement using language or gesture, eye contact, display of affect, and imitation. We analyzed videotaped footage in five-second intervals and coded for the presence of target behaviors, and we established interjudge reliability in coding at 80 percent (that is, that the judges agreed on the appropriate codes at least 80 percent of the time) before pretreatment assessments. Two investigators then analyzed the pre- and post-treatment data. Following the analysis, the two investigators

independently coded 20 percent of the footage, and we documented 89 to 91 percent agreement across the behaviors coded. In addition to this analysis of social engagement, we recorded clinical observations of social communication.

### Results

Table 1 shows the production of social-engagement behaviors before and after treatment. Alex showed dramatic increases in socially engaged behaviors from before to after. Chris's gains were more modest. Clinical observations indicated that both children were highly motivated to interact with the robot, and both were more interactive with clinicians without the robot following treatment. We observed several significant behaviors (in the absence of the robot) after treatment that had not been observed before, including greeting clinicians by waving (and in Chris's case, saying their names), symbolic pretend play with toys, sharing toys, and decreased restricted interests and repetitive behaviors.

Our case study and technology development have uncovered many important challenges and research opportunities. One of the most critical is to identify clinical approaches that allow us to reach statistically sound conclusions for a problem with as many confounding factors as autism therapy. Such factors include frequently sharp differences in behaviors among children with autism; the complexity of coordinating therapy across a large team of therapists, caregivers, and educators; and the vast range of

Table 1. Social engagement behaviors before and after treatment.

Child	No. of engagements initiated		No. of engagements responded to	
	Pretreatment	Post-treatment	Pretreatment	Post-treatment
Alex	11	120	108	488
Chris	48	65	107	146

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potential robot and user interface technologies. ■

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## References

1. *Diagnostic and Statistical Manual of Mental Disorders*, 4th ed., Am. Psychiatric Assoc., 2000.
2. C. Lord and R. Paul, "Language and Communication in Autism," *Handbook of Autism and Pervasive Developmental Disorders*, D.J. Cohen and F.R. Volkmar, eds, Wiley, 1997, pp. 195–225.
3. P.A. Prelock and S.H. Contompas, "Autism and Related Disorders: Trends in Diagnosis and Neurobiologic Considerations," *Autism Spectrum Disorders: Issues in Assessment and Intervention*, P.A. Prelock, ed., Pro-ed, 2006, pp. 3–63.
4. P.A. Prelock and A. Ducker, "Understanding and Assessing the Social-Emotional Development of Children with ASD," *Autism Spectrum Disorders: Issues in Assessment and Intervention*, P.A. Prelock, ed., Pro-ed, 2006, pp. 251–301.
5. A. Duquette, F. Michaud, and H. Mercier, "Exploring the Use of a Mobile Robot as an Imitation Agent with Children with Low-Functioning Autism," *Autonomous Robots*, vol. 24, no. 2, 2008, pp. 147–157.
6. B. Robins, K. Dautenhahn, and J. Dubowsky, "Does Appearance Matter in the Interaction of Children with Autism with a Humanoid Robot?," *Interaction Studies*, vol. 7, no. 3, 2006, pp. 479–512.
7. H. Kozima, C. Nakagawa, and Y. Yasuda, "Designing and Observing Human-Robot Interactions for the Study of Social Development and its Disorders," *Proc. IEEE Int'l. Symp. Computational Intelligence in Robotics and Automation*, IEEE, 2005, pp. 41–46.
8. J.M. Seibert, A.E. Hogan, and P.C. Mundy, "Assessing Interactional Competencies: The Early Social-Communication Scales," *Infant Mental Health J.*, vol. 3, no. 4, 1982, pp. 244–258.
9. K. Dautenhahn, "Roles and Functions of Robots in Human Society: Implications from Research in Autism Therapy," *Robotica*, vol. 21, no. 4, 2003, pp. 443–452.
10. N. Giullian et al., "Detailed Requirements for Robots in Autism Therapy," *Proc. IEE Int'l Conf. Systems, Man, and Cybernetics*, IEEE, 2010, pp. 2595–2602.
11. S. Kopp and I. Wachsmuth, "Model-Based Animation of Co-verbal Gesture," *Proc. Computer Animation*, IEEE, 2002, pp. 252–257.
12. E. Salas and S. M. Fiore, eds., *Team Cognition: Understanding the Factors that Drive Process and Performance*, Am. Psychological Assoc., 2004.
13. M. Yim, "Astronauts Must Program Robots," *Proc. AAAI Spring Symp.: To Boldly Go Where No Human-Robot*



*Team Has Gone Before*, AAAI, 2006, pp. 59–63.

14. J.C.C. Gillesen et al., “From Training to Robot Behavior: Towards Custom Scenarios for Robotics in Training Programs for ASD,” *Proc. IEEE Int’l Conf. Rehabilitation Robotics*, IEEE, 2011, pp. 387–393.
15. K.V. Hindriks, M.A. Neerincx, and M. Vink, “The iCat as a Natural Interaction Partner: Playing Go Fish with a Robot,” *Proc. Autonomous Agents and Multi-Agent Systems*, Springer, 2011, pp. 212–231.
16. A.J. Ko et al., “Improving the Design of Visual Programming Language

Experiments Using Cognitive Walk-throughs,” *J. Visual Languages and Computing*, vol. 13, no. 5, 2002, pp. 517–544.

17. J.A. Atherton and M.A. Goodrich, “Supporting Clinicians in Robot-Assisted Therapy for Autism Spectrum Disorder: Creating and Editing Robot Animations with Full-Body Motion Tracking,” *Proc. Robotics Science and Systems Workshop Human-Robot Interaction*, 2011; [http://hri.willowgarage.com/workshops/RSS2011/RSS\\_2011\\_\\_Human-Robot\\_Interaction.html](http://hri.willowgarage.com/workshops/RSS2011/RSS_2011__Human-Robot_Interaction.html).
18. B. Robins et al., “Effects of Repeated Exposure to a Humanoid Robot on

Children with Autism,” *Designing a More Inclusive World*, S. Keates et al., eds., Springer, 2004, pp. 225–236.

19. C. Kasari, S. Freeman, and T. Paparella, “Joint Attention and Symbolic Play in Young Children with Autism: A Randomized Controlled Intervention Study,” *J. Child Psychology and Psychiatry*, vol. 47, no. 2, 2006, pp. 611–620.

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